Suzaku Detection of the Charge Exchange Emission and Observation for Soft X-ray Diffuse Emissions

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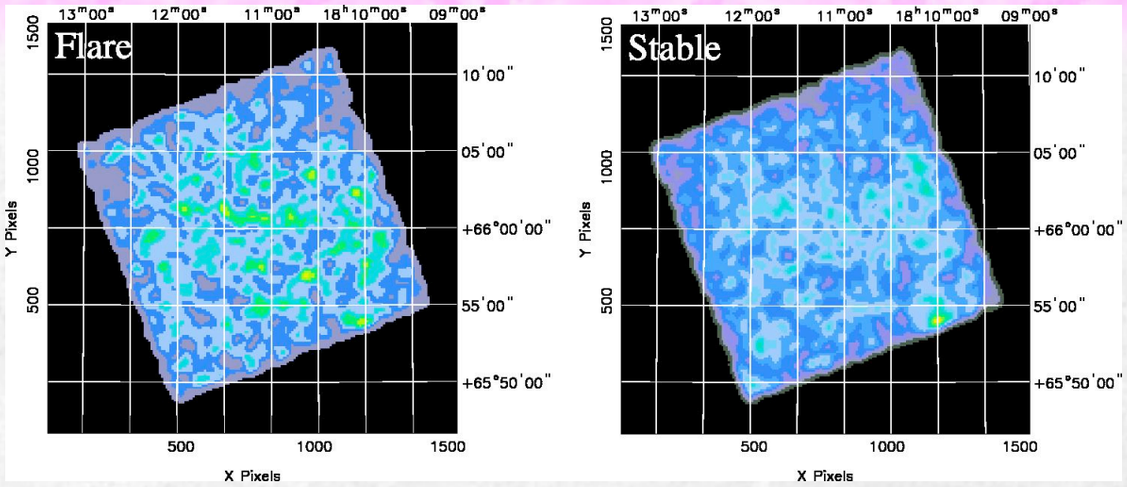
Local Bubble and Beyond II , 21-24 Apr 2008 at Philadelphia

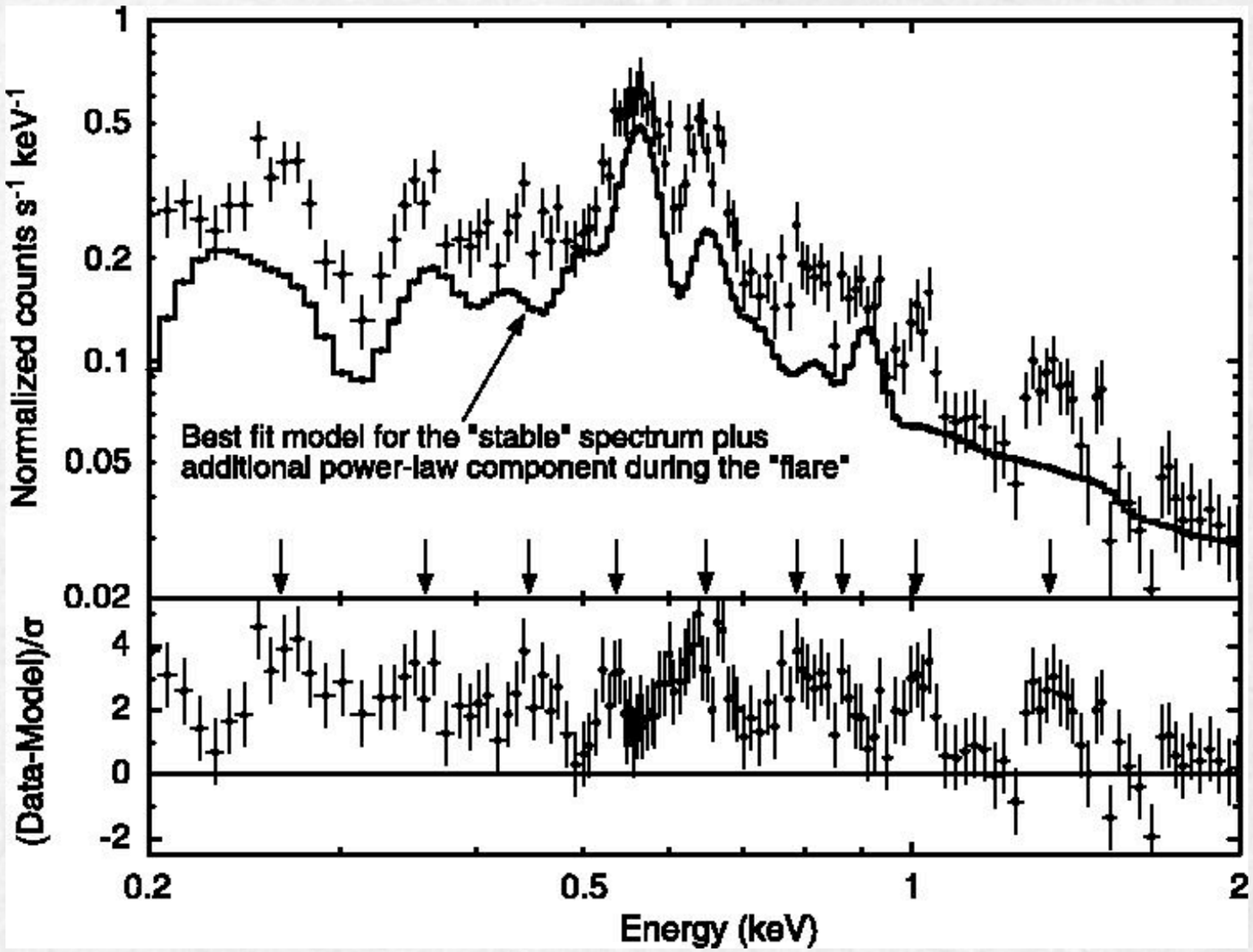
Outline

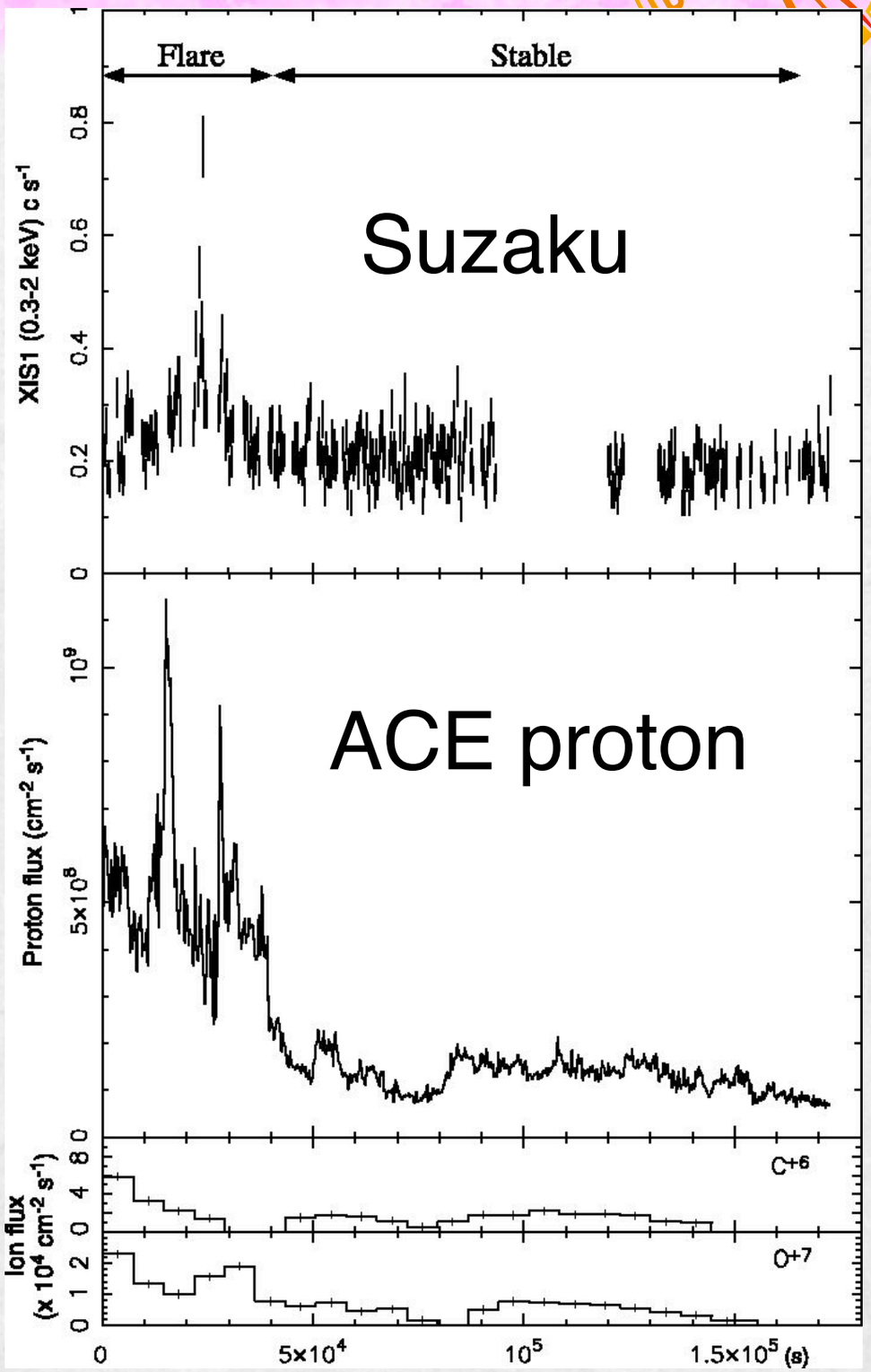
- Suzaku enable us real imaging-spectroscopy for Oxygen lines from all over the Universe. We will show some recent example about ..

- Detection of the Solar-wind Charge Exchange (SWCX) emission
  - Emission from “CUSP” region above the polar
  - Emission from the equatorial plane
- Local Bubble with Shadowing technique
- M-band problem in soft X-ray background.
- Halo around the Galaxy
  - Plan for absorption / emission combined study
  - Abundance pattern and origin of the Halo

SWCX emission found in NEP





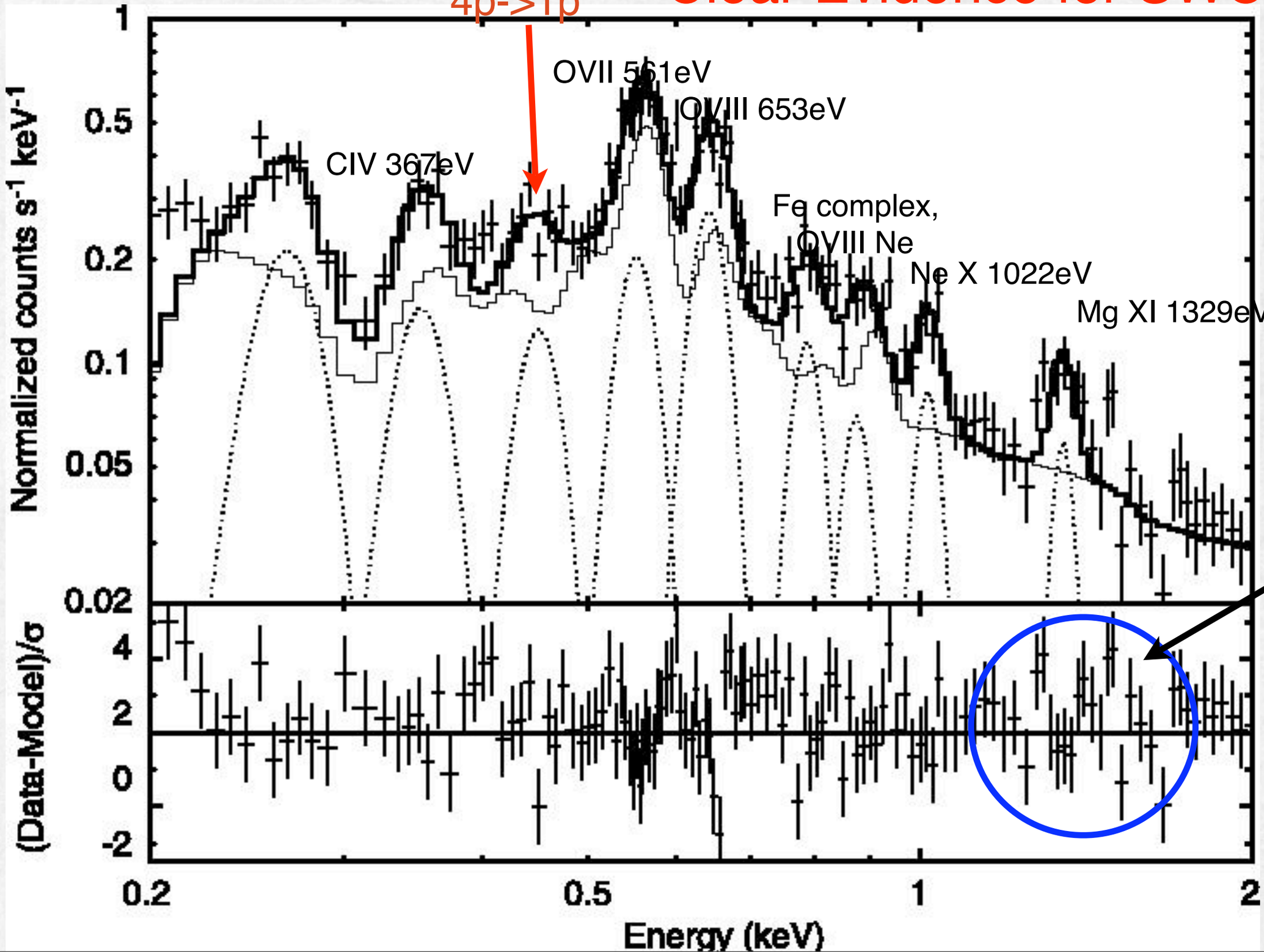


Fujimoto et al. 2007, PASJ, 59, S133

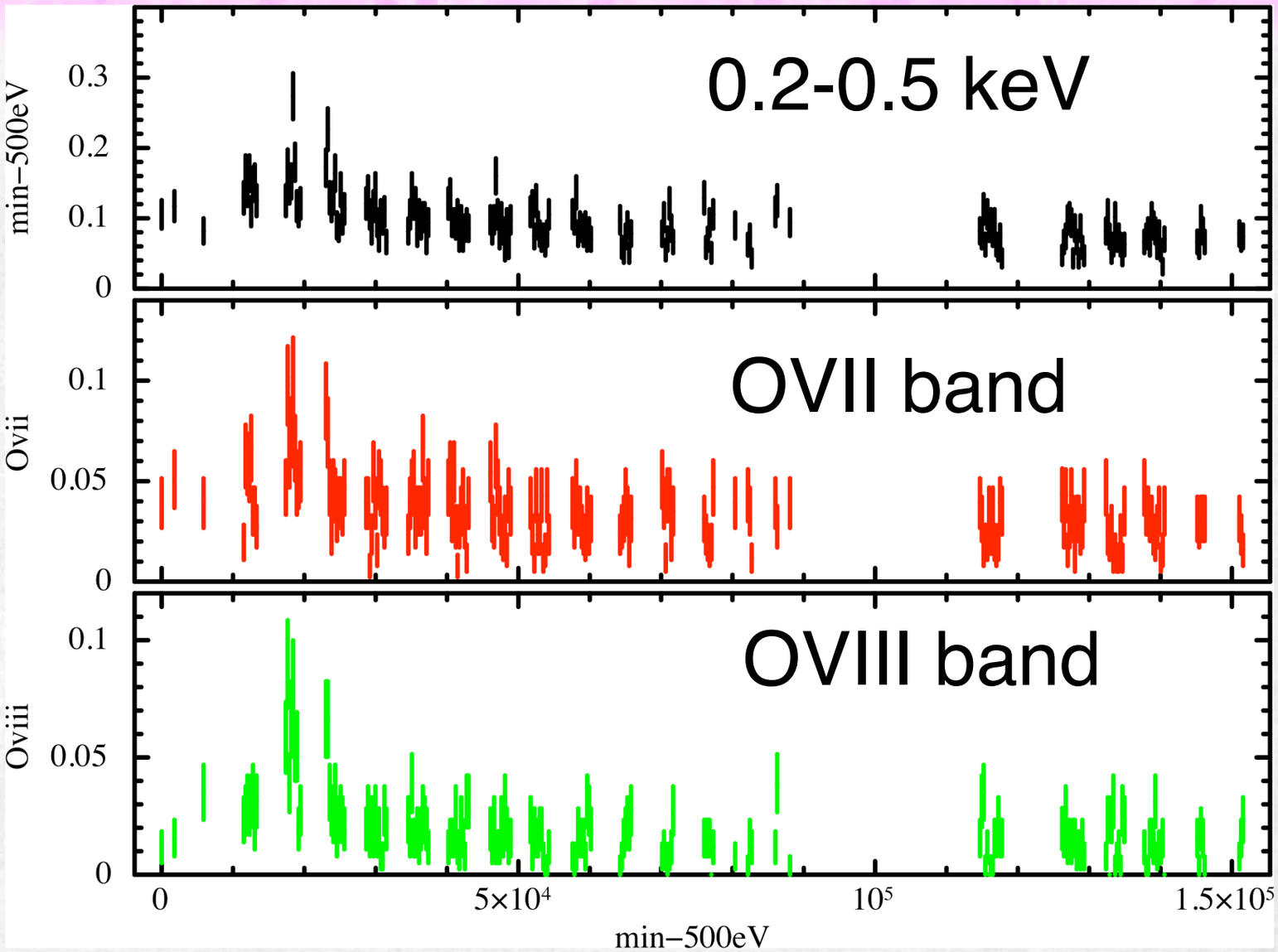
Eenrgy Spectrum during the flare

CIV 459 eV
4p->1p

Clear Evidence for SWCX

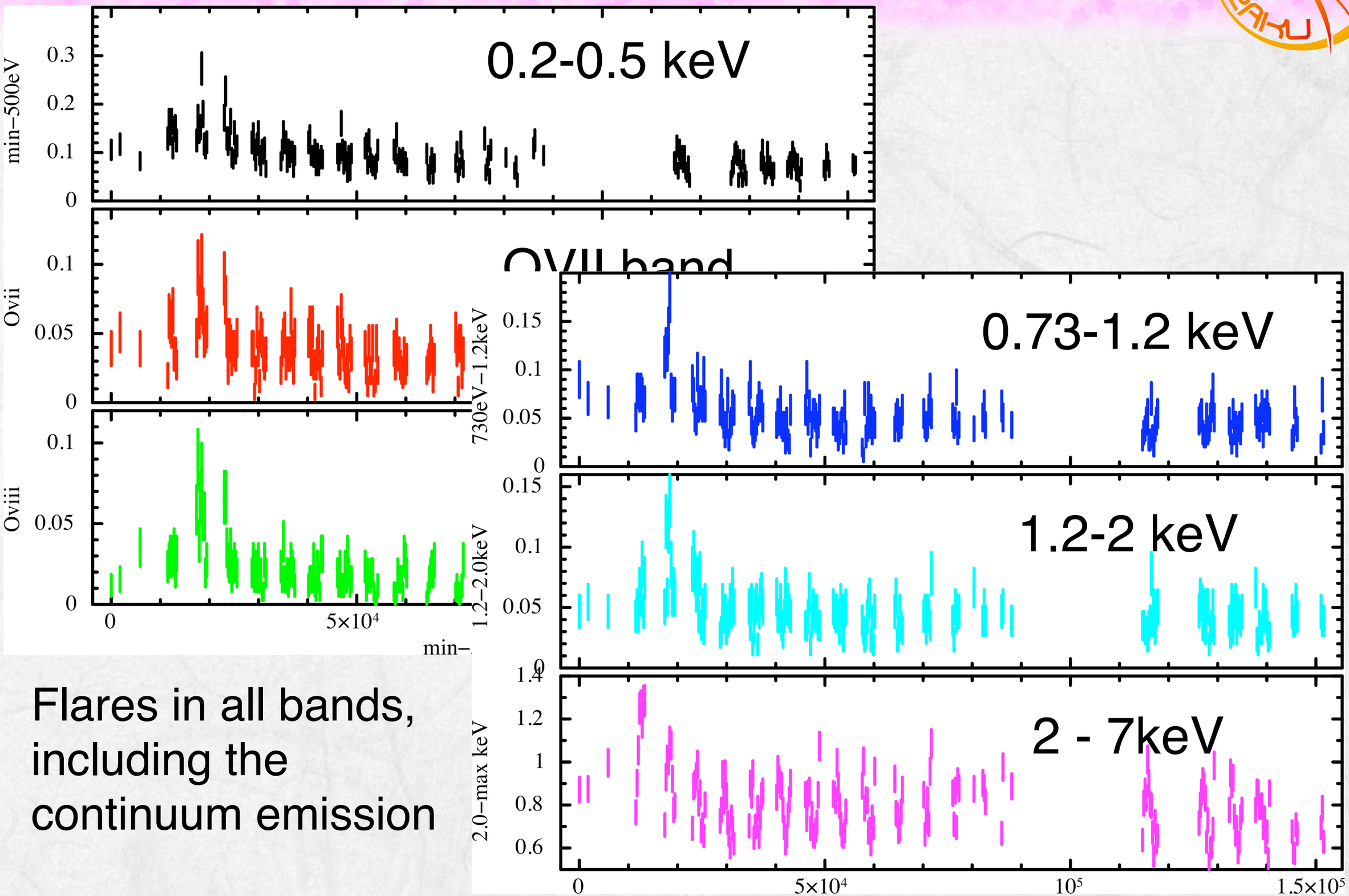


Light Curves



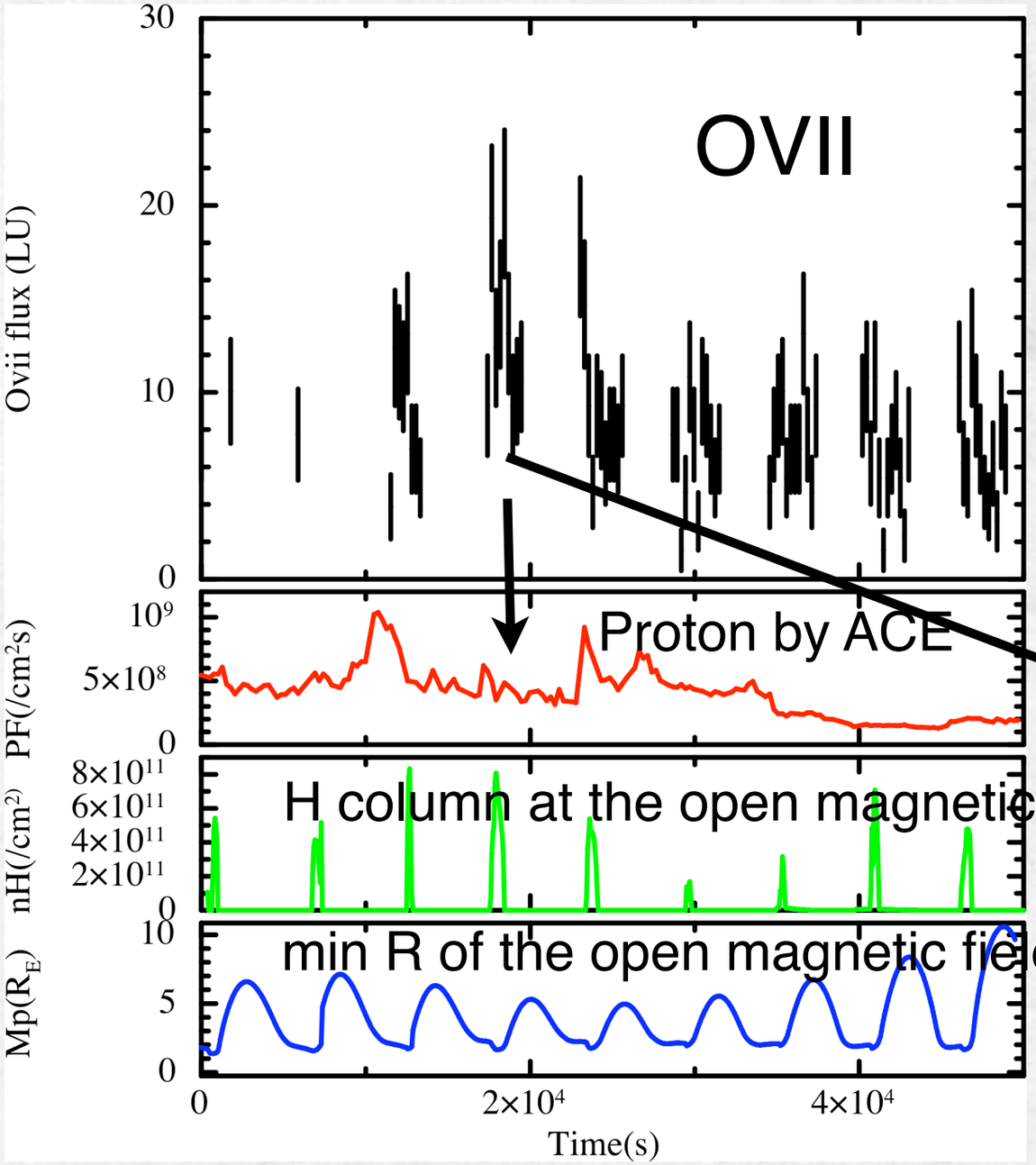
Flares in all bands, including the continuum emission

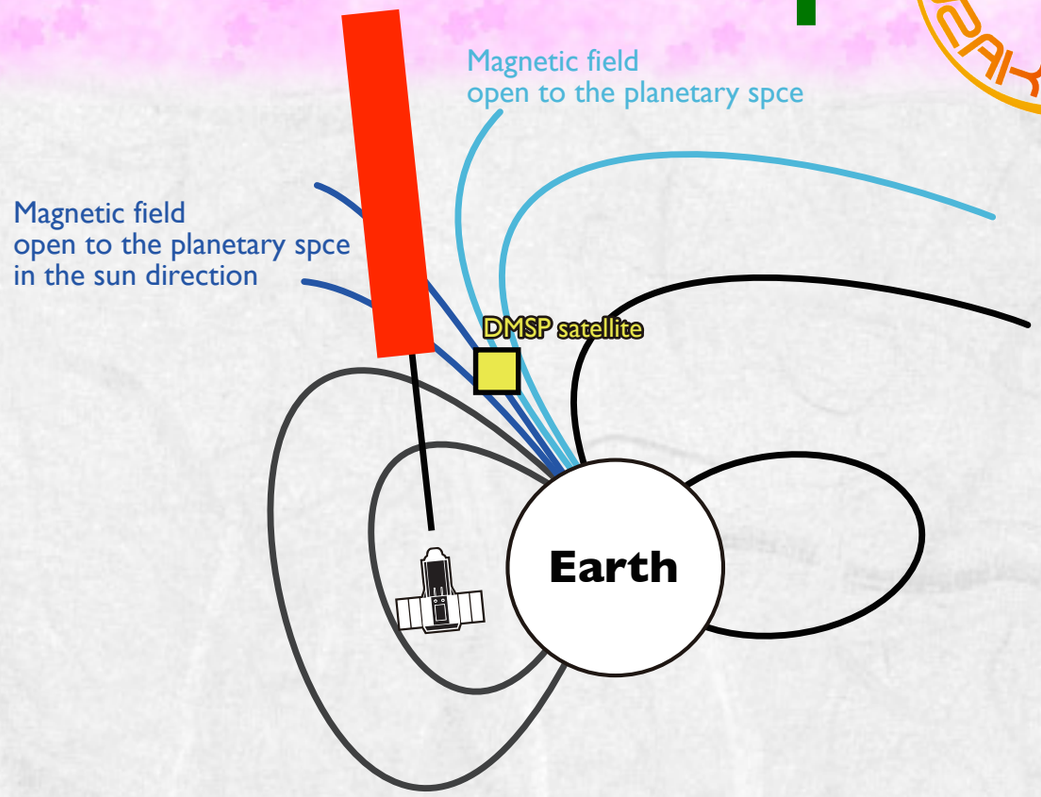
Light Curves



Flares in all bands, including the continuum emission

Solar wind came from “Cusp”?

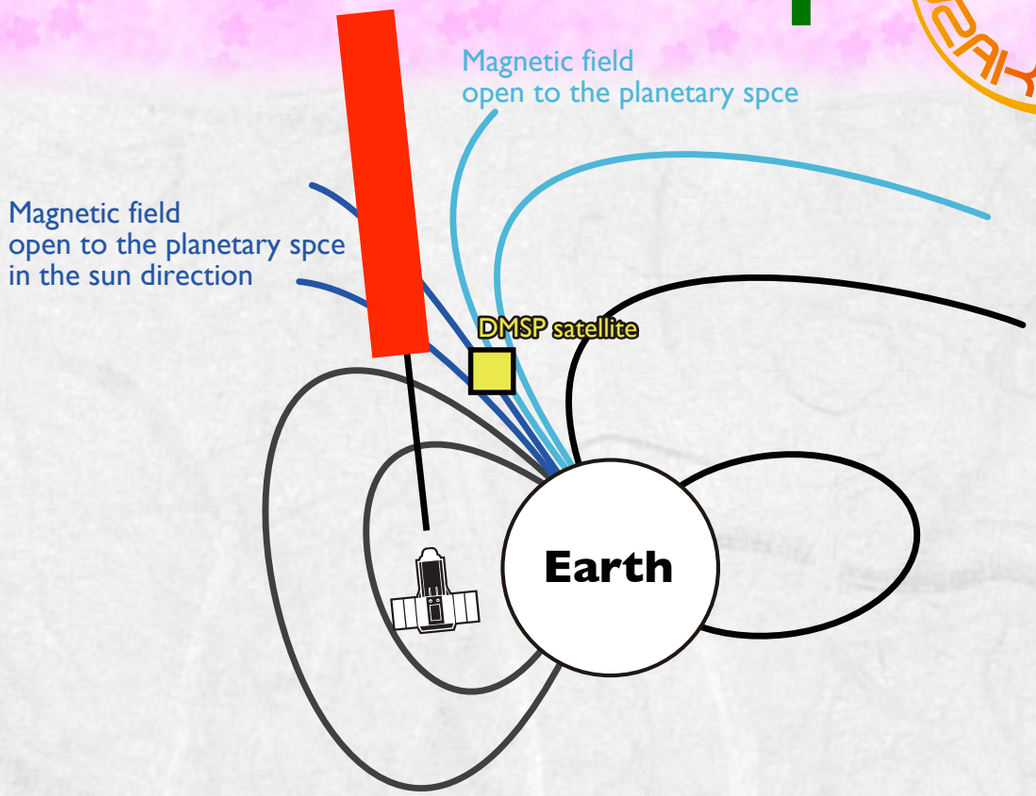


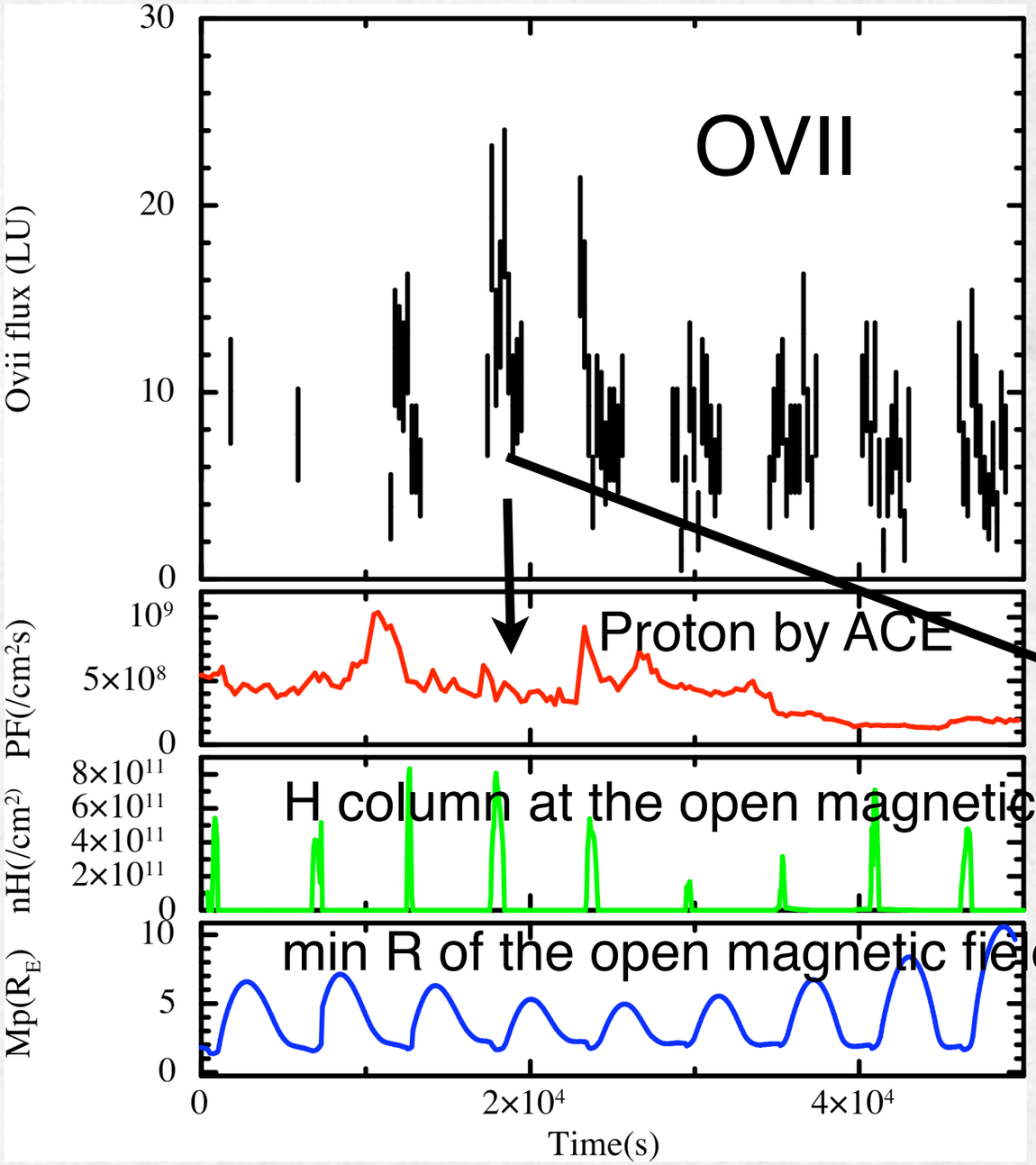


At the time of flux peak,
SW through the “CUSP” was detected by a DMSP crossed the same line of field.

DMSP proton

Solar wind came from “Cusp”?





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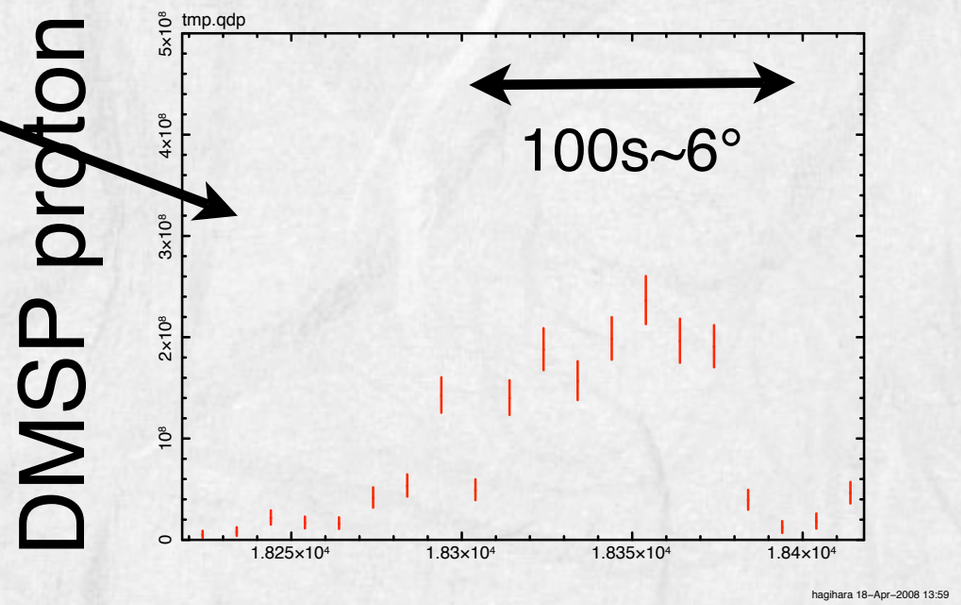
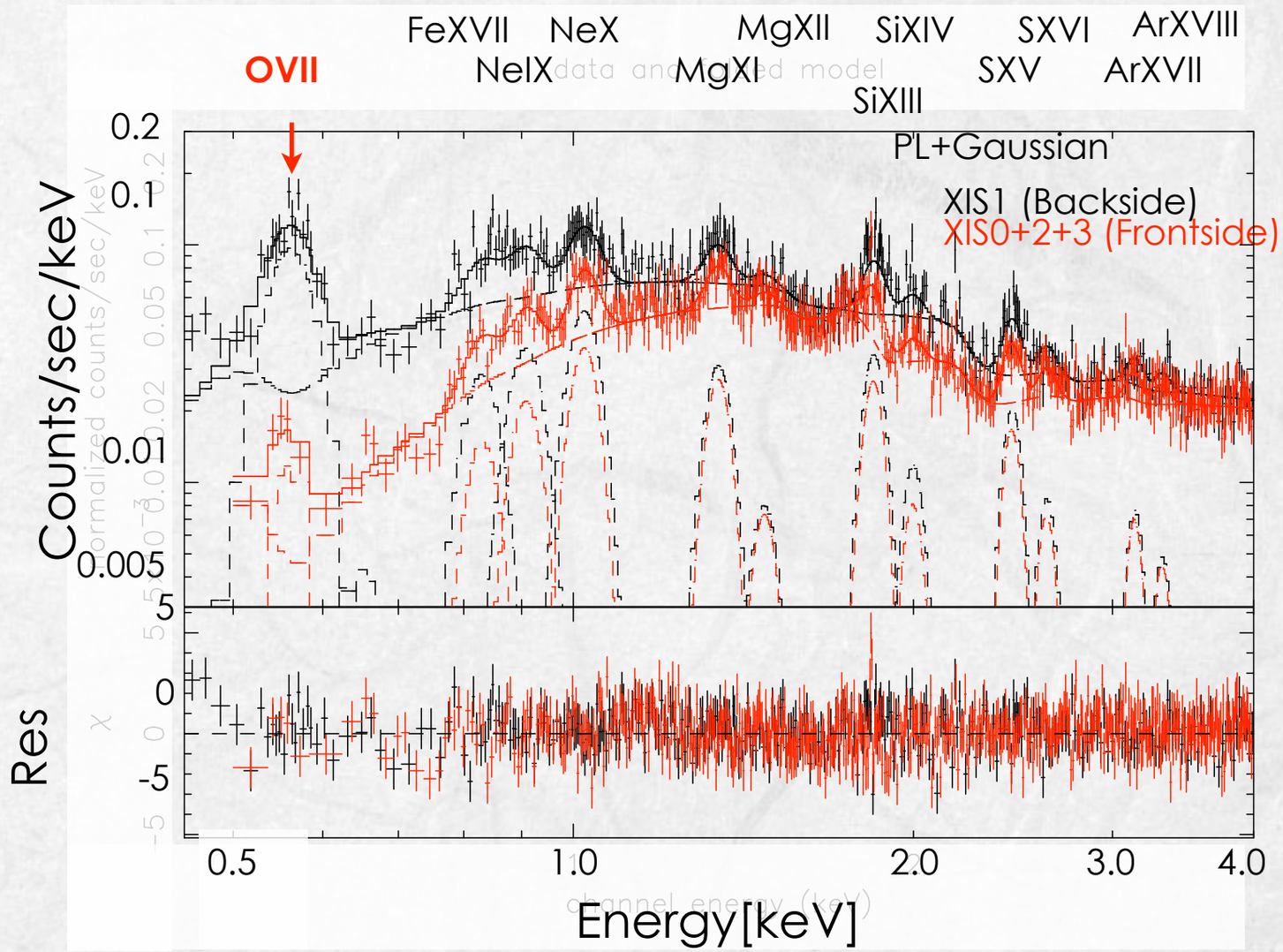


SWCX from exosphere on the equatorial plane

Observation: Galactic Ridge (no point source) at (l,b)=(-28.46,-2.04) or (Ra,Dec)=(281.0,-4.07)
2005/Oct/28-30



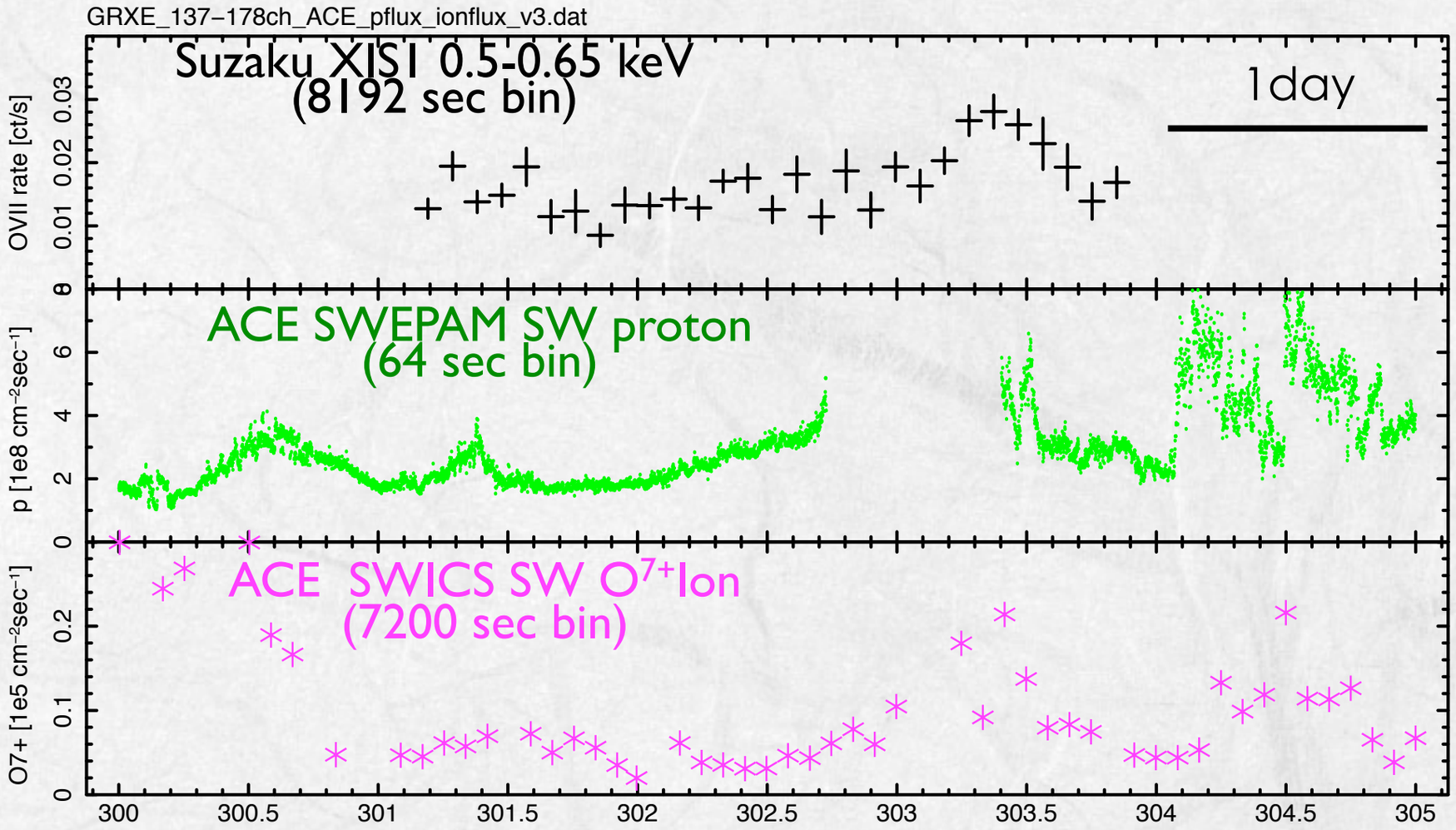
Strong OVII line

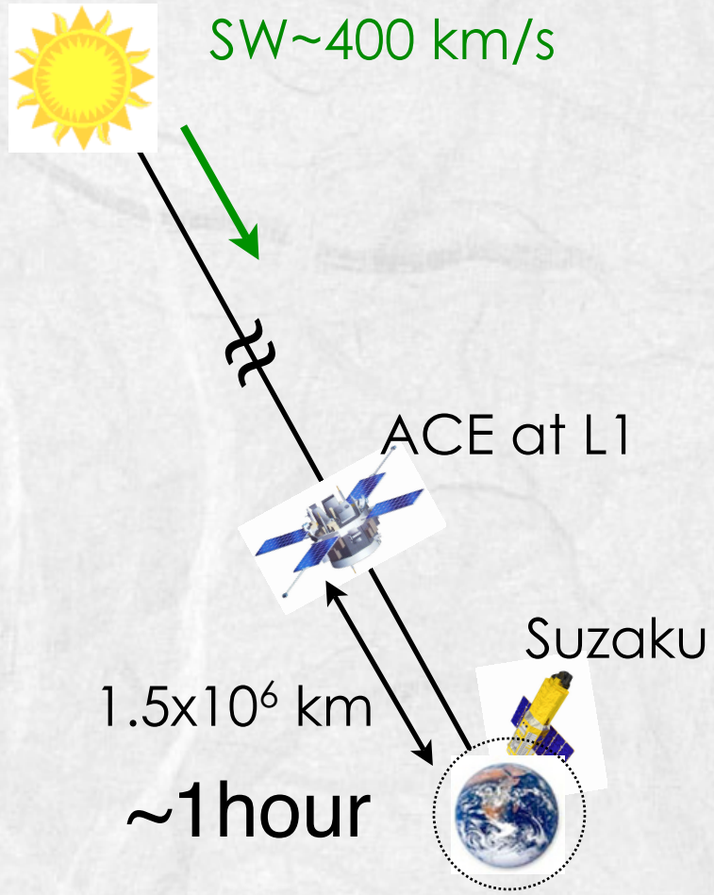
11+/- 2 ph/cm²/s/str

560 +/- 3 eV

width < 6 eV

Light curve of emission line and Ion flux by ACE

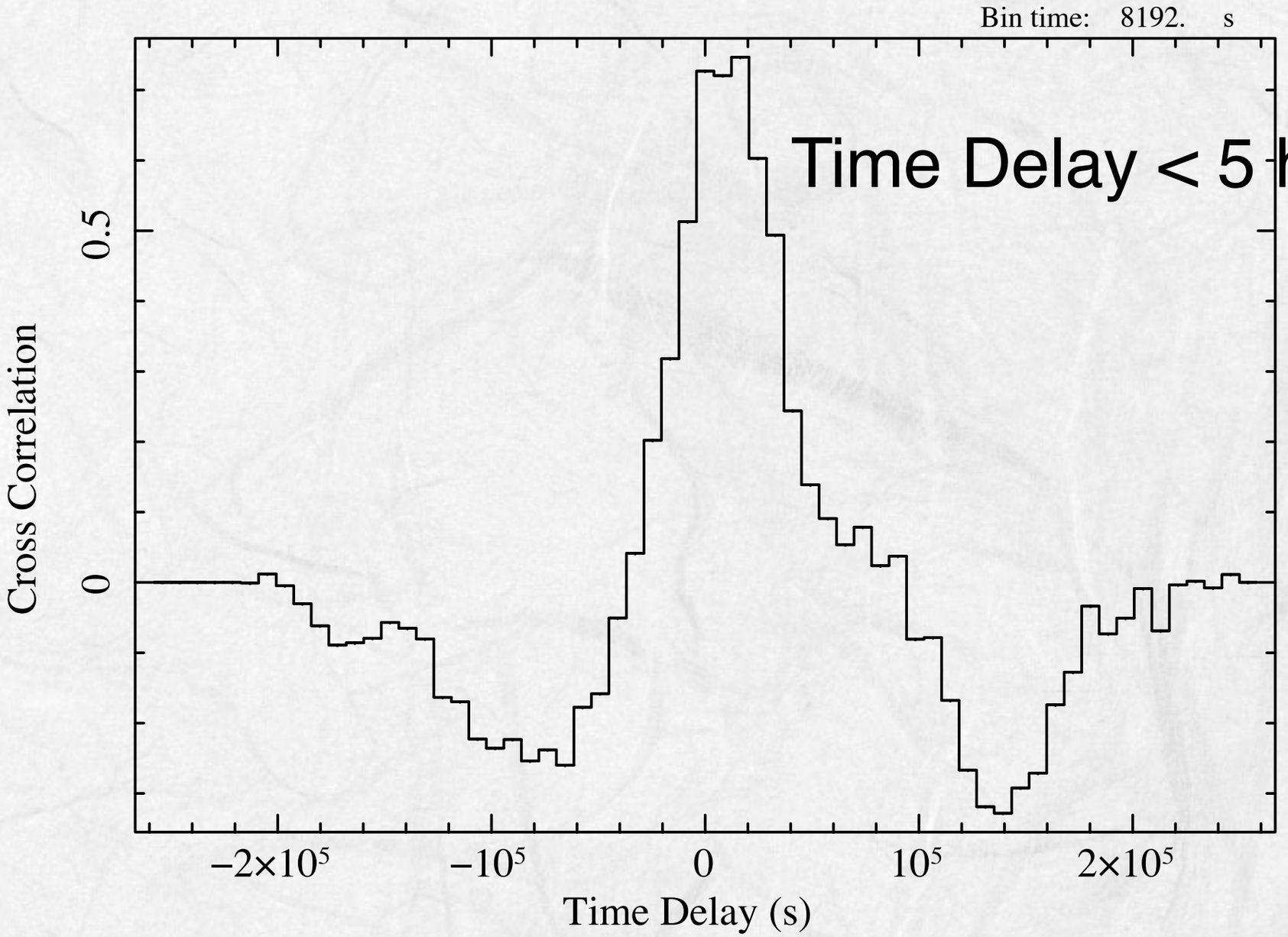




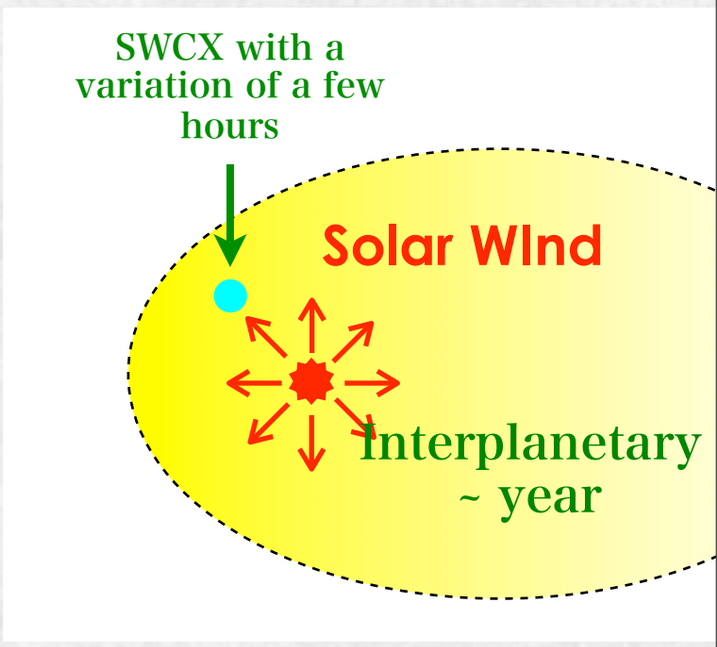
Time variation of the emission & Ion flux correlate well, with a delay < 5 hour

⇒ SWCX at the exosphere

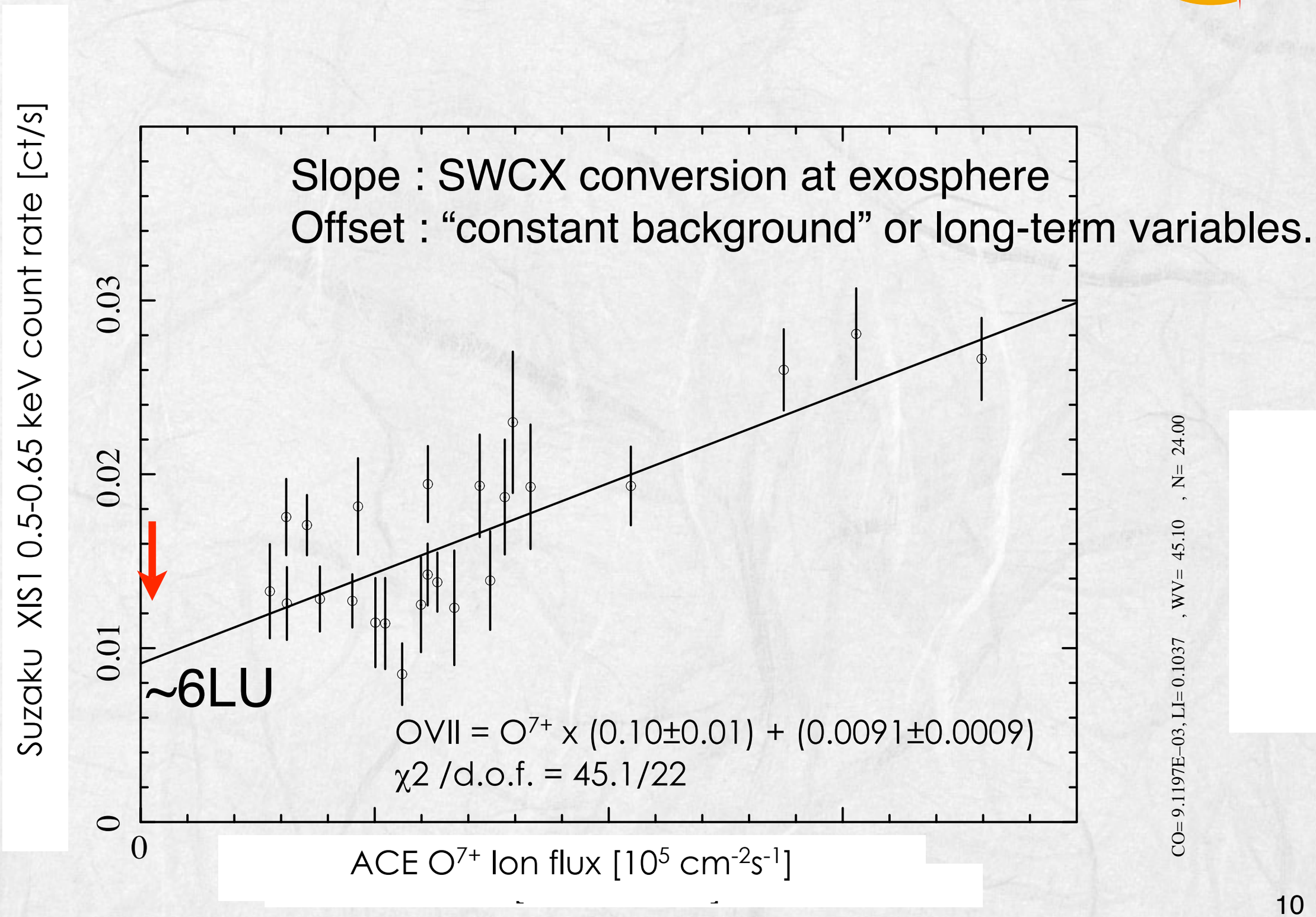
Cross-Correlation between O7+ vs OVII emission



ACE O7+ Ion vs Suzaku OVII emission line intensity



O7+ vs O emission line



Reproduction of the SWCX intensity

- Assume SWCX where the magntic field is open

$$O^{7+} + H \rightarrow O^{6+} + H^{+} + h\nu$$

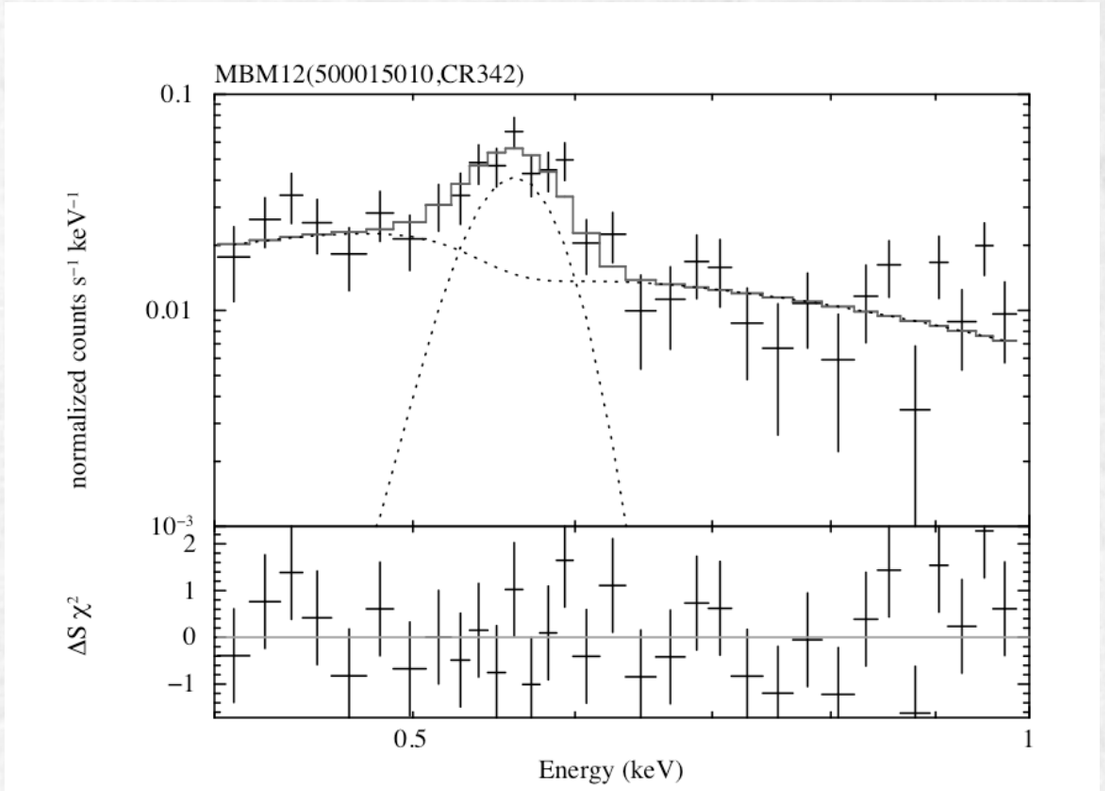
$$f_{\mathrm{OVII}} = \frac{1}{4\pi} \int_{l_{\mathrm{min}}}^{l_{\mathrm{max}}} \sigma f_{\mathrm{O7+}} n_{\mathrm{H}}(l) dl$$

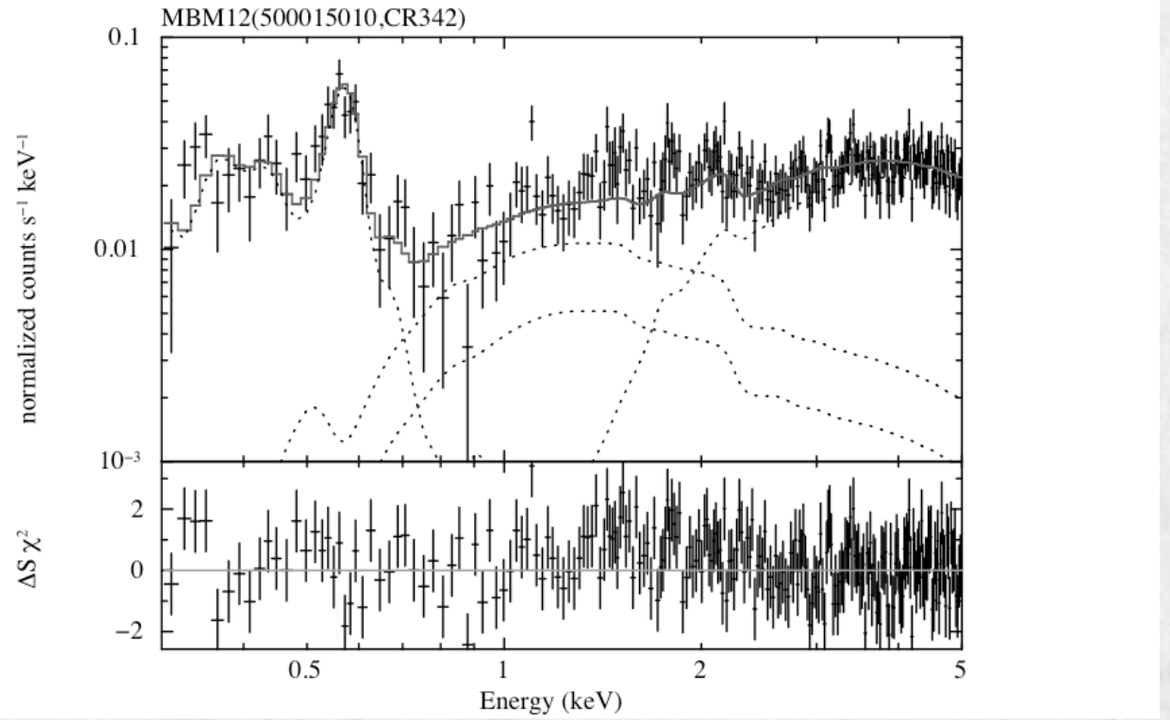
  - O7+ ion flux: estimated by ACE or DMSP
  - Cross section ~ 6×10^{-15} cm^2 (Wegmann+ 1998)
  - Magnetic Field: Stable model with GEOPACK 1995
  - neutral H density
    - $nH(r) = 25\ (10R_E/r)^3$ $R<11R_E$ (Cravens+ 2001)
    - $nH(r) = 70\ \exp(-r/8.2R_E)$ $R> 11R_E$ (Ostgarrd+ 2003)
- NEP: Data is factor of 3 higher
- Galactic Plane: factor of 50 higher
  - we have started to collaborate with geophysics people.

Shadowing Observation of LB

Smith et al. 2007, PASJ, 59, S141
and also please check his poster

On-clound observation of MBM12 (60-270 pc?), a significant OVII line was detected.

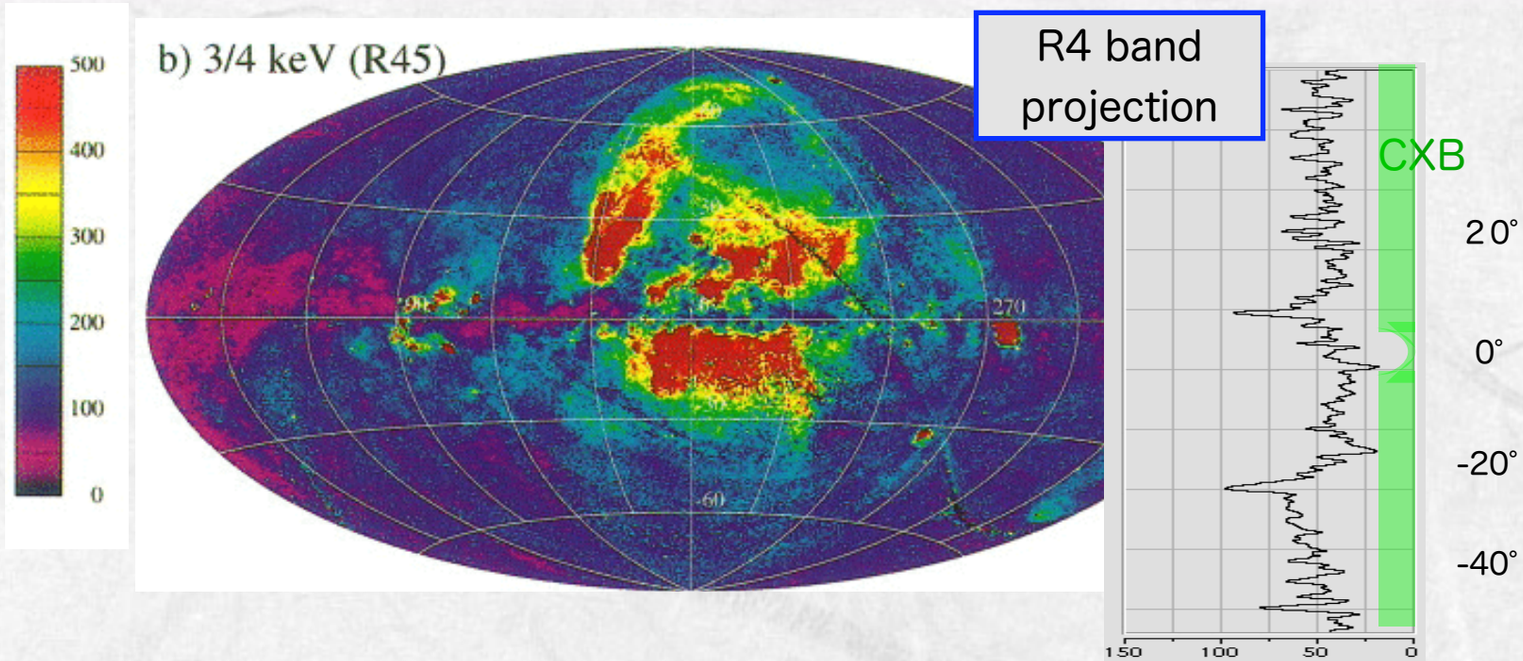




OVII line intensity depends on the models, 2.2-3.6 ph/cm^2/sec/str

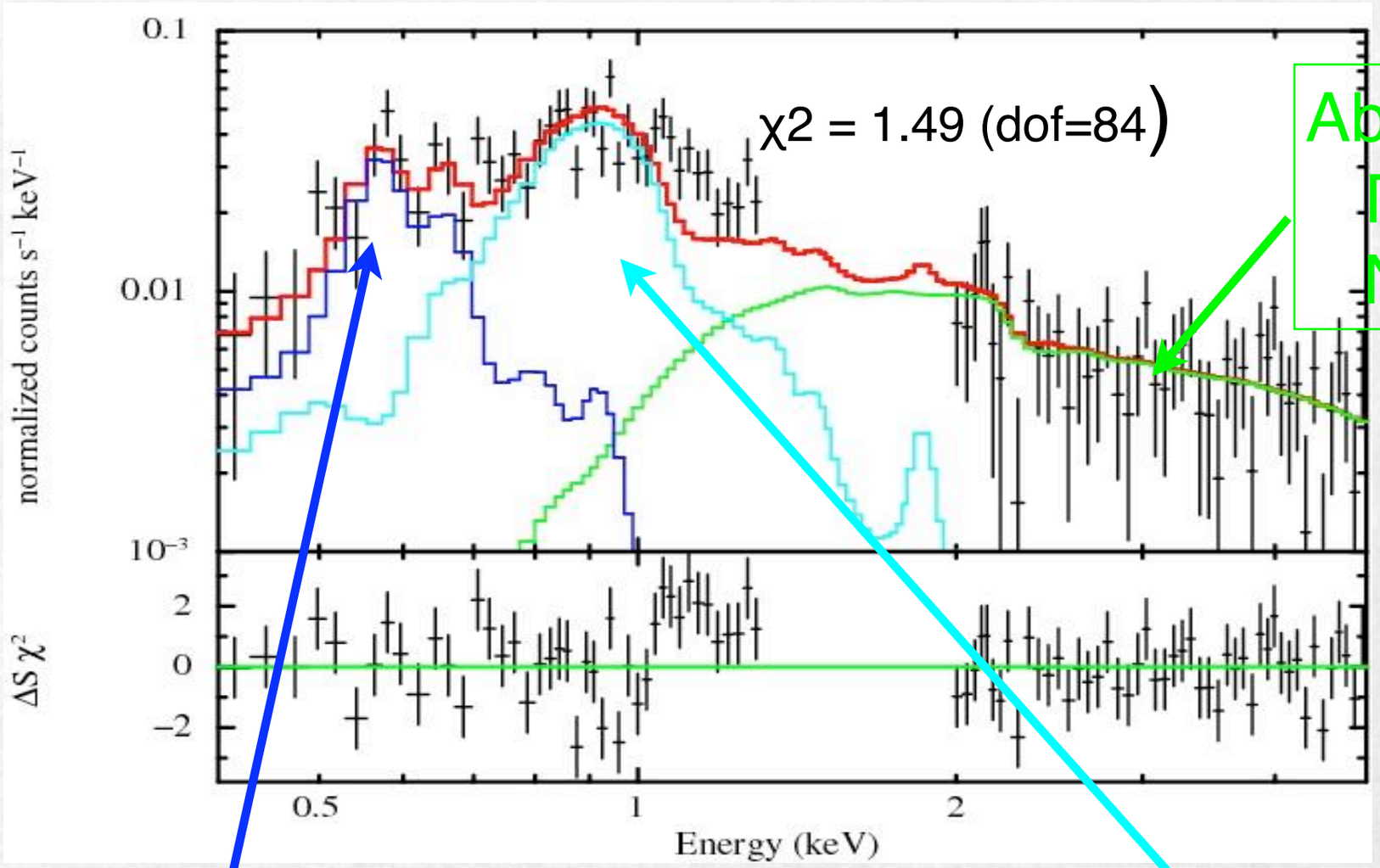
with a thermal model of kT=0.1-0.12 keV (T = 10^6.2 ~ emissivity peak)

Soft X-ray diffuse background and M-band problem



- R4 band image of RASS is very uniform expect local structures
- At high latitude, 60% of the background comes from the CXB (McCammon et al. 2002)
- On the Galactic plane, CXB should be absorbed.
- Some component compensates the absence of the CXB “M-band problem”
- We tried a spectroscopic study at (l,b)=(235,0)

Energy Spectrum at (235,0)



Absorbed CXB
Γ=1.4 (fixed)
Norm=7.5 ph/cm2/s/sr/keV @1keV

LB comp with OVII
unabsorbed APEC
kT=0.18 keV
EM=0.019cm^{-6}pc

Themal Emission with Fe-L complex
unabsorbed APEC
kT=0.77 keV
EM=0.017 cm^{-6}pc

Contribution of each component between 0.5 and 1 keV

	kT~0.1 keV LHB ?	High kT comp	CXB	TOTAL
Anti-center (235.0,0.0)	0.34 (36%)	0.57 (61%)	0.02 (3%)	0.92 (100%)
High latitude (Lockman hole)	0.46 (40%)	-	0.70 (60%)	1.16 (100%)

[10^{-8} erg/s/cm^2/sr]

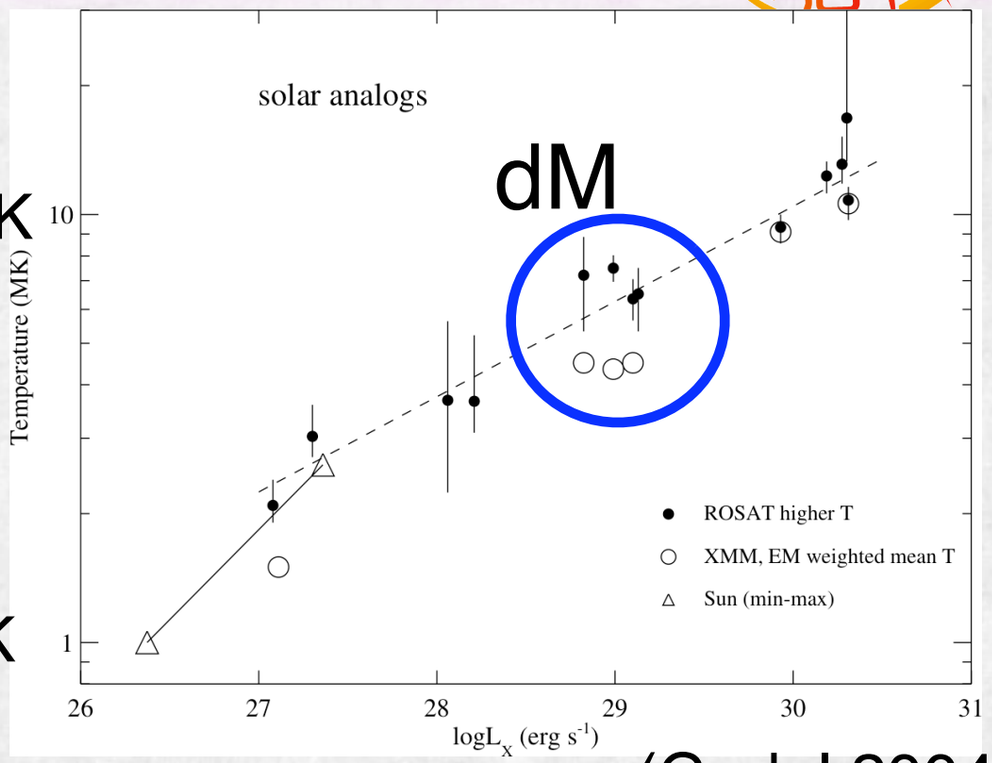
- If high T component is truly diffuse, the p/K > 10^4 cm^{-3}K
- What's are on the Galactic plane with kT ~ 0.8 keV?
  - Stars! Especially typical dM star has coronal emission with Lx~10^{29} and kT~ 0.8 keV.

Estimate of stellar contribution

- Calculate expected logN-logS of M stars
- Spatial distribution of
  - Stars: Bahcall & Snoneira 1984

$$N(R,Z) = n_0 \exp\left(-\frac{Z}{325\ \mathrm{pc}} - \frac{R}{3.5\ \mathrm{kpc}}\right)$$

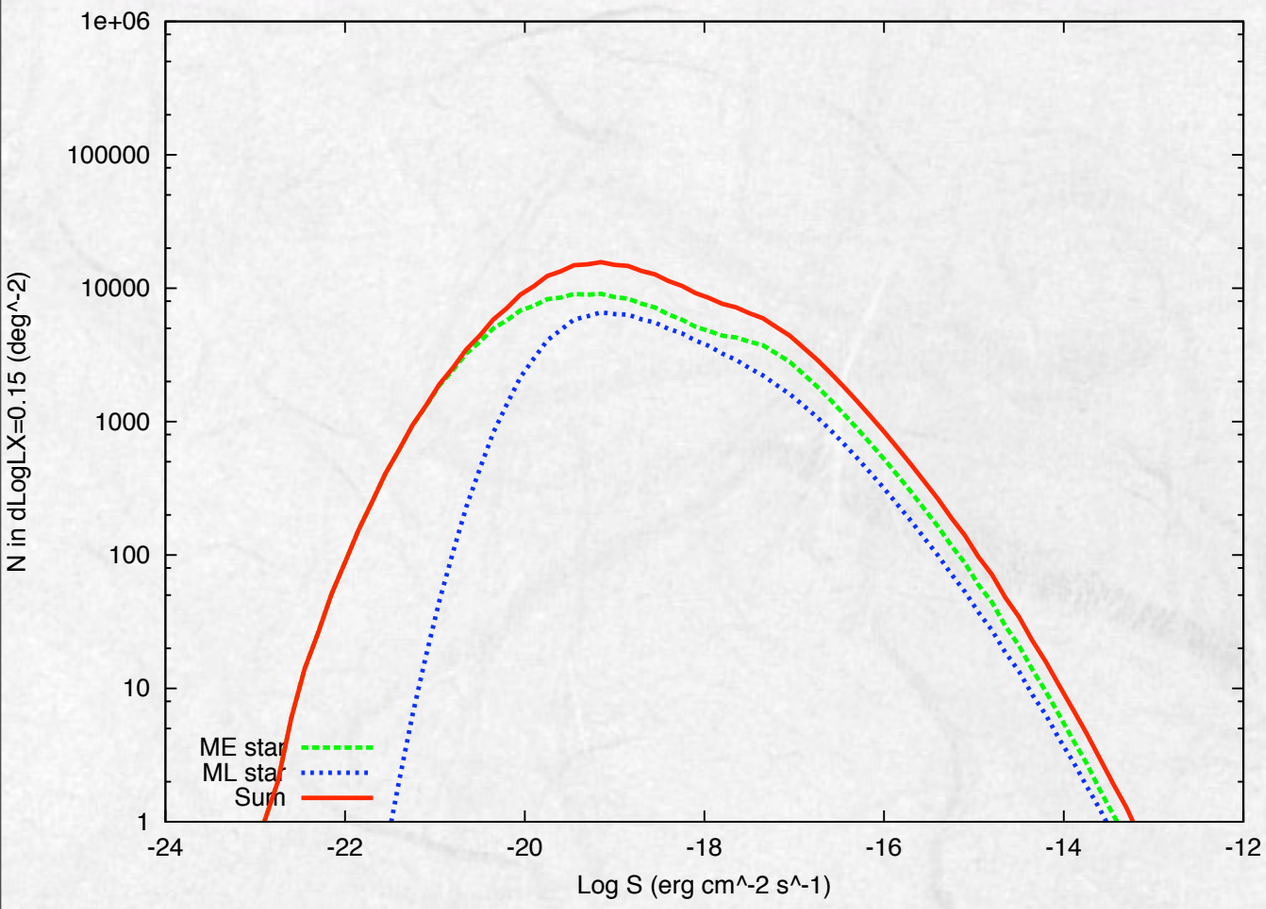
  - Hydrogen: Cox 2005
- M stars (Kunz &Snowden 2001)
  - Density
  - Luminosity distribution
  - Energy spectra
    kT = 0.8 keV Z=1solar

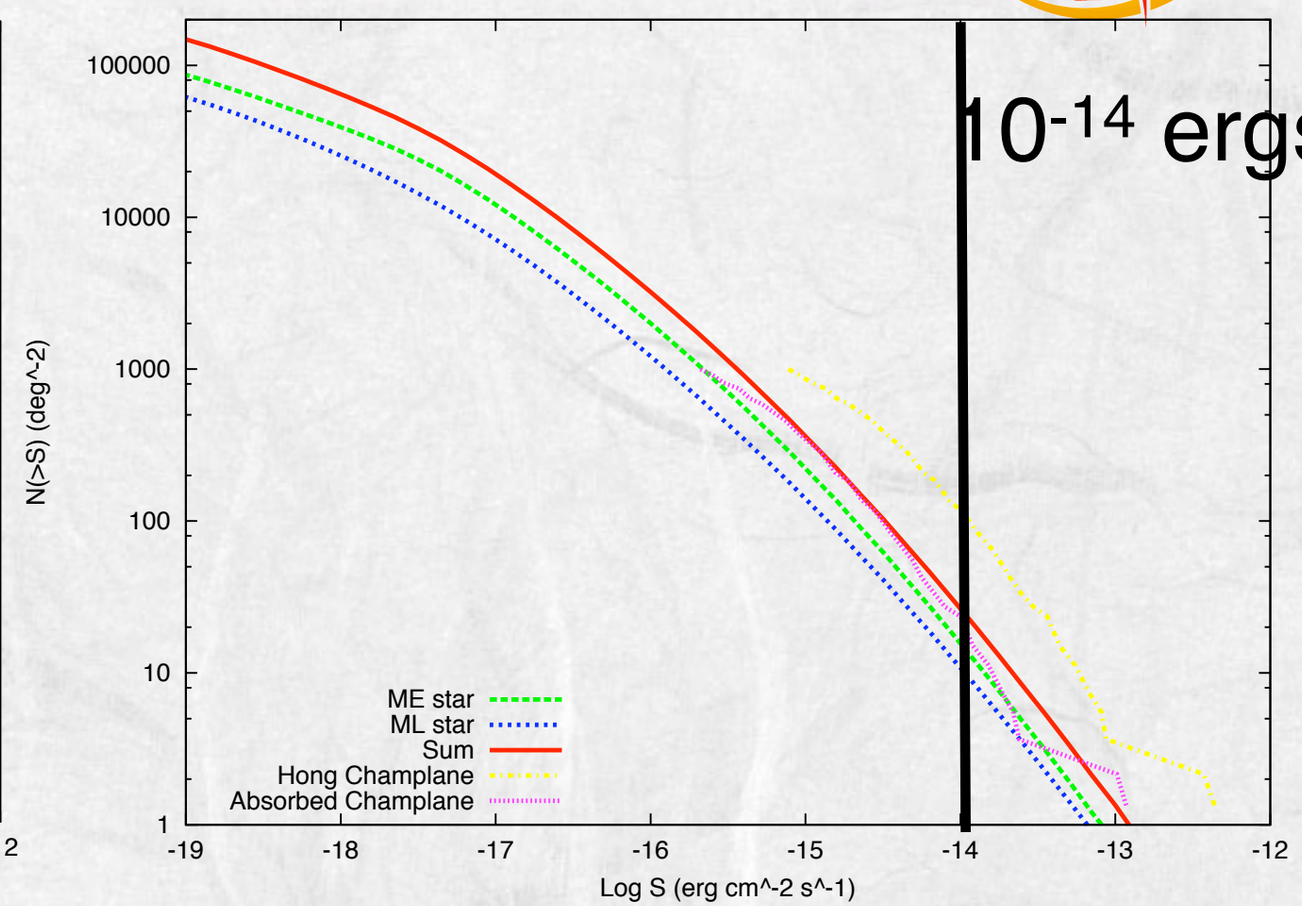


(Gudel 2004)

	0-0.15 Gyr	0.15-1 Gyr	1-10 Gyr
midplane density	4.28×10^{-3}	8.96×10^{-3}	3.29×10^{-2}
<logLx>	29.19	27.89	26.86
sigma of <log Lx>	0.32	0.72	0.77

logN-logS relation

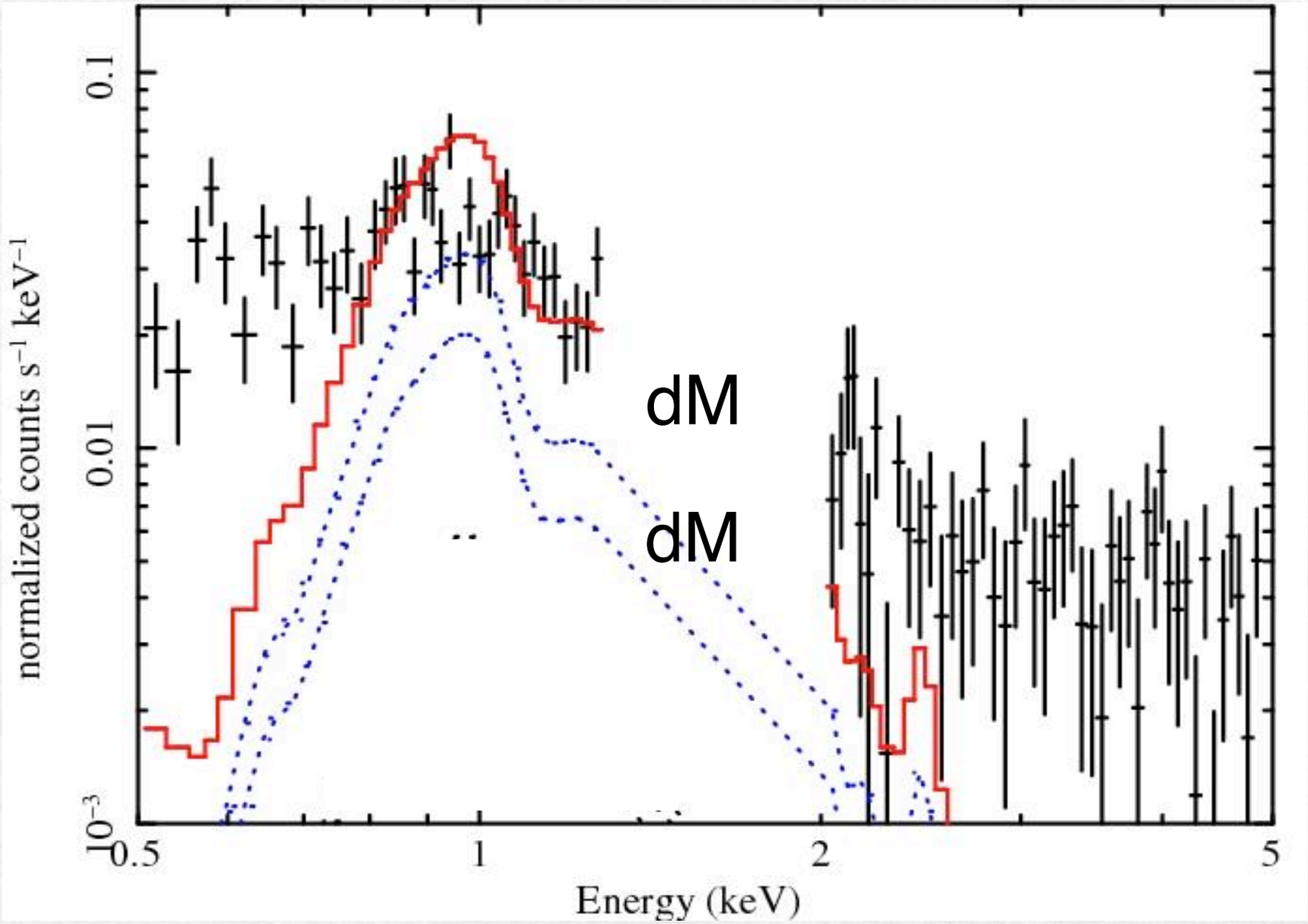




- Contributes source distance < 1 kpc
- Total flux with $S<10^{-14}$ ergs sources is 7.5×10^{-9} erg/cm^2/s/str
  - Consistent with the data within 30% accuracy.
  - Still there could be some contribution from truly diffuse plasma, but stars is not negligible

Synthesized spectra

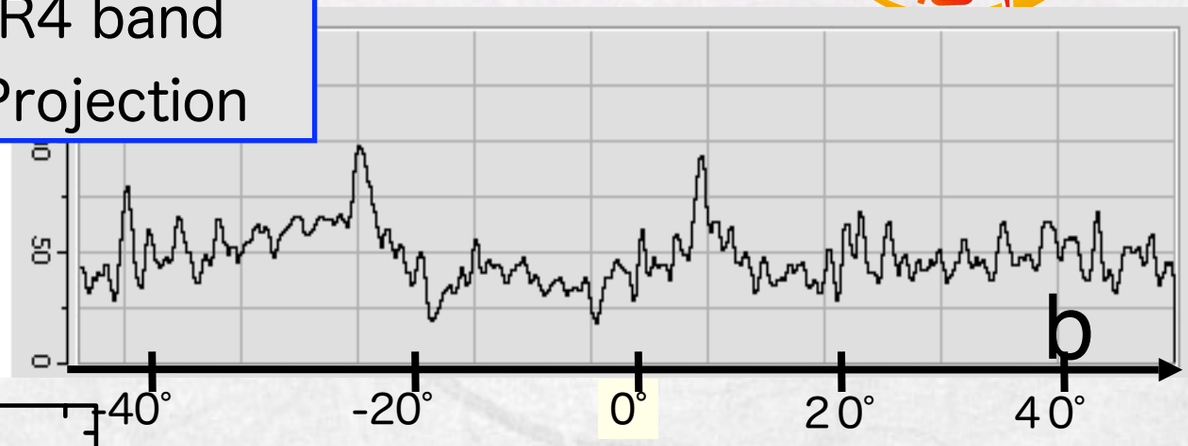
Well represent Fe-L complex



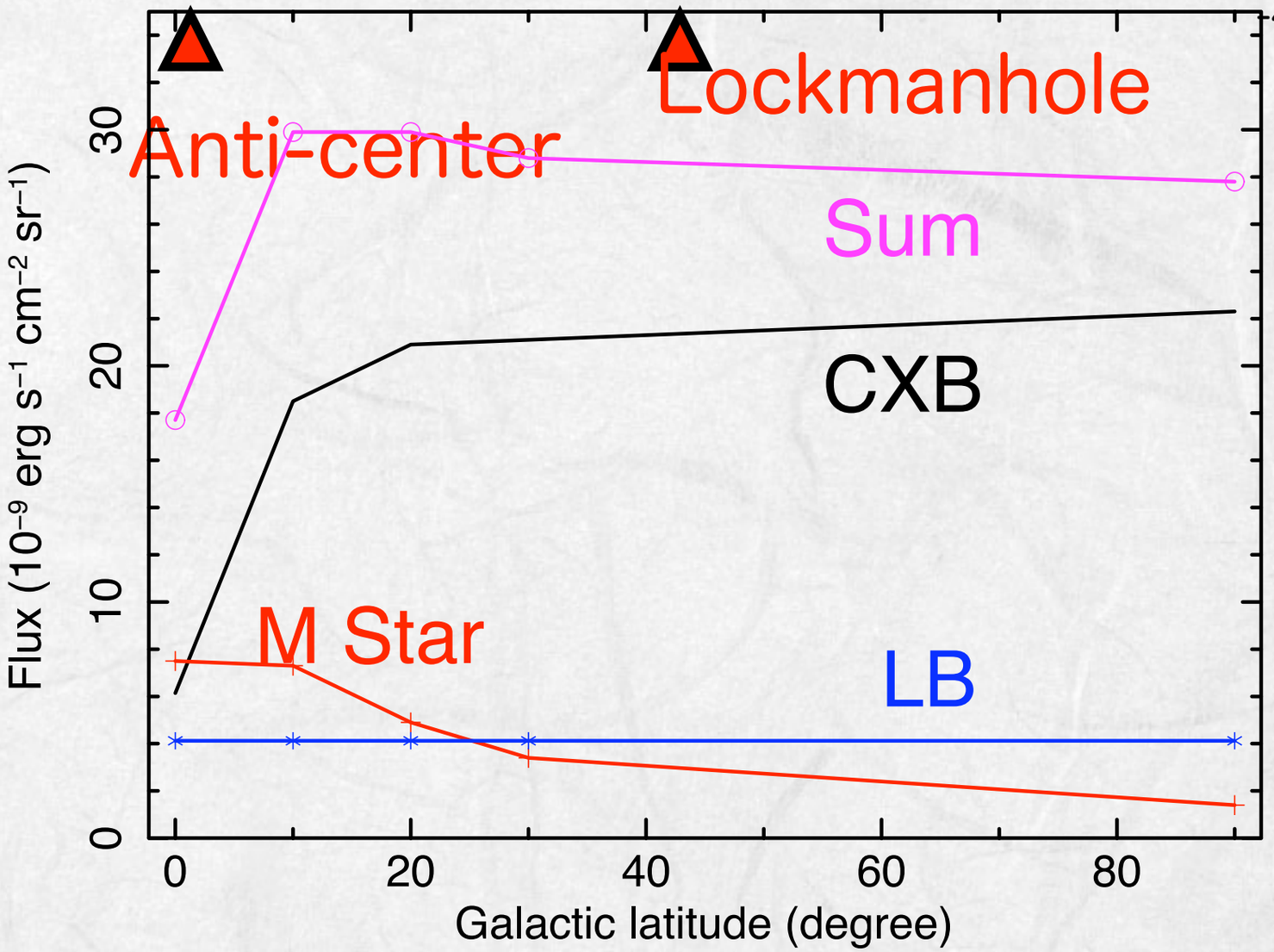
Convolution with ROSAT response is not yet done

b dependence of stars and CXB

R4 band
Projection



0.5-2 keV flux estimation



b↗ star ↘ &CXB↗

The sum shows a flat distributin

M band problem is almost solved by M stars.

Absorption/Emission study

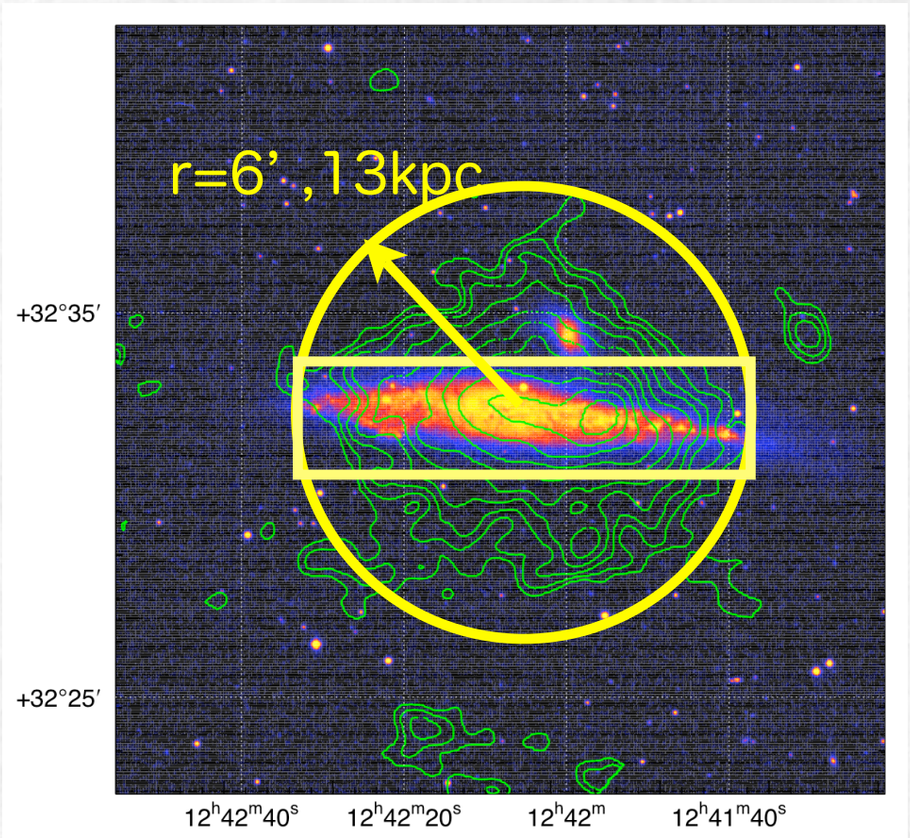
Source	OVII EW (eV)	N_{OVII} ($10^{16}cm^{-2}$)	z or D	absorption	Suzaku
LMC X-3	0.53±0.16	1.3 - 3.1	50 kpc	Wang et al. (2006)	2006 Apr
4U1820-303	$1.2^{+0.5}_{-0.3}$	1.6 - 5.4	7.6 kpc	Futamoto et al. (2004), Yao &	2006 Sep
PKS 2155-304	0.43±0.09	≥ 0.45*	0.116	Nicastro et al. (2002) Rasmussen et al.	AO-3 (Hagihara)
Mkn 421	0.41±0.04	≥ 0.48*	0.030	Rasmussen et al. (2003, 2006)	AO-3 (Yao)
3C273	0.70±0.12	≥ 0.76*	0.158	Rasmussen et al. (2003)	

Already presented by Dr.Wang talk

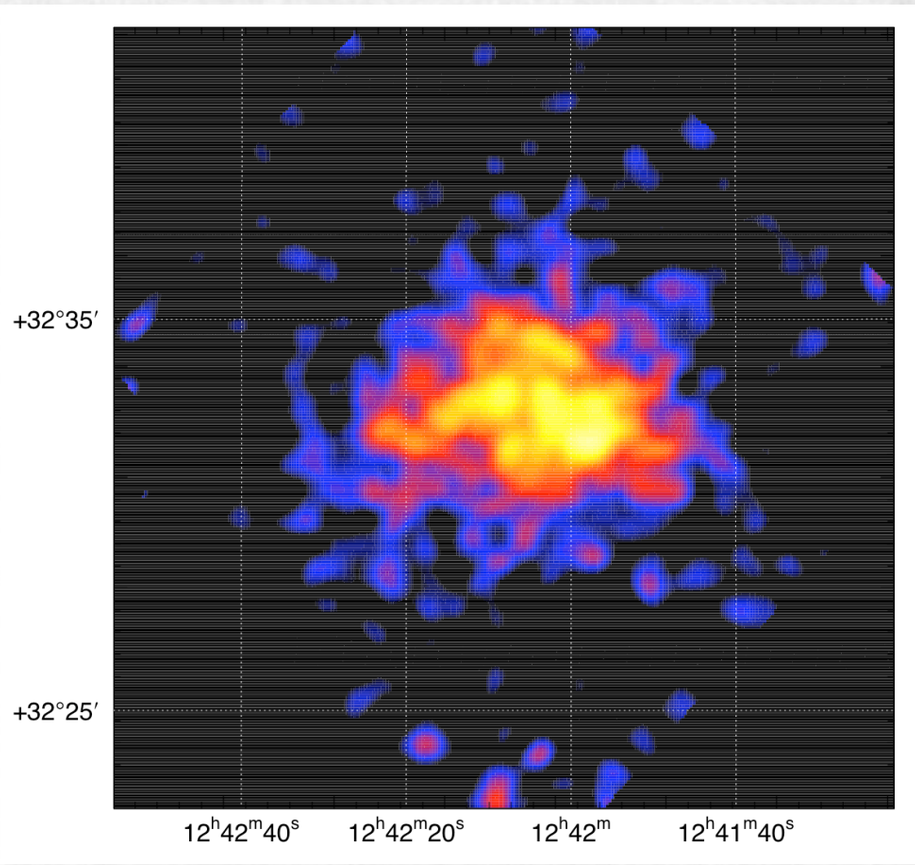
2 observation will be done within this year

Halo around a starburst galaxy

NGC 4631: edge-on starburst at 7.5 Mpc

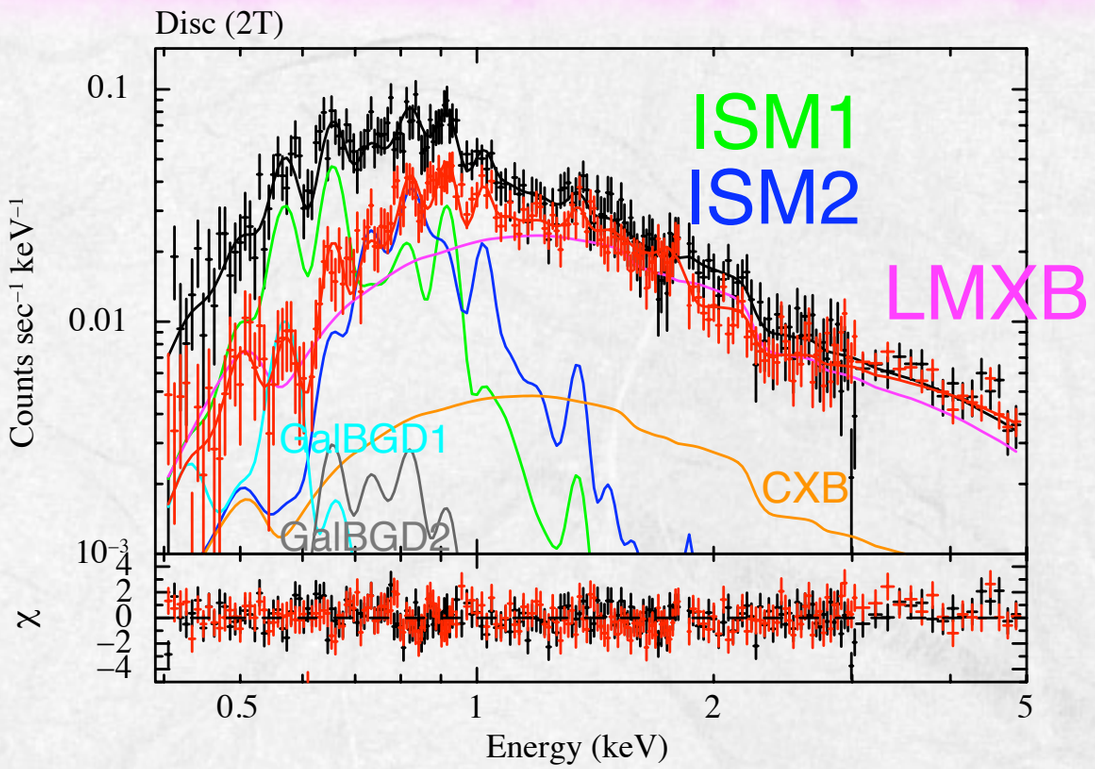


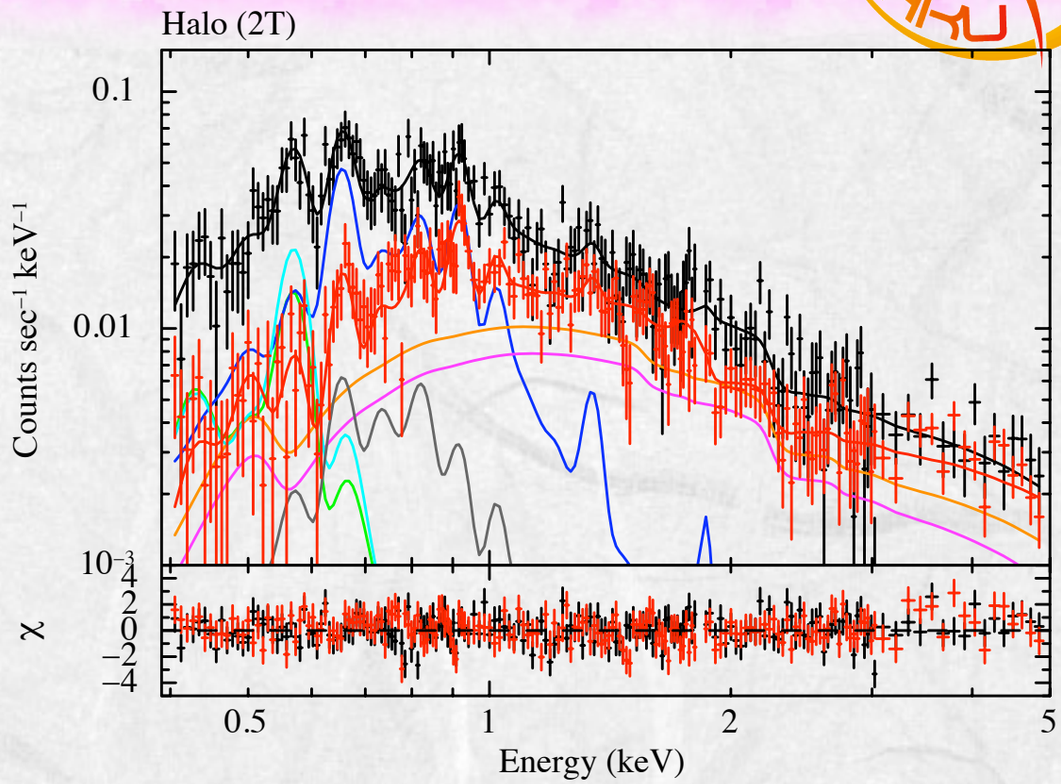
DSS+0.5-2 keV contour



0.6-0.7 keV image

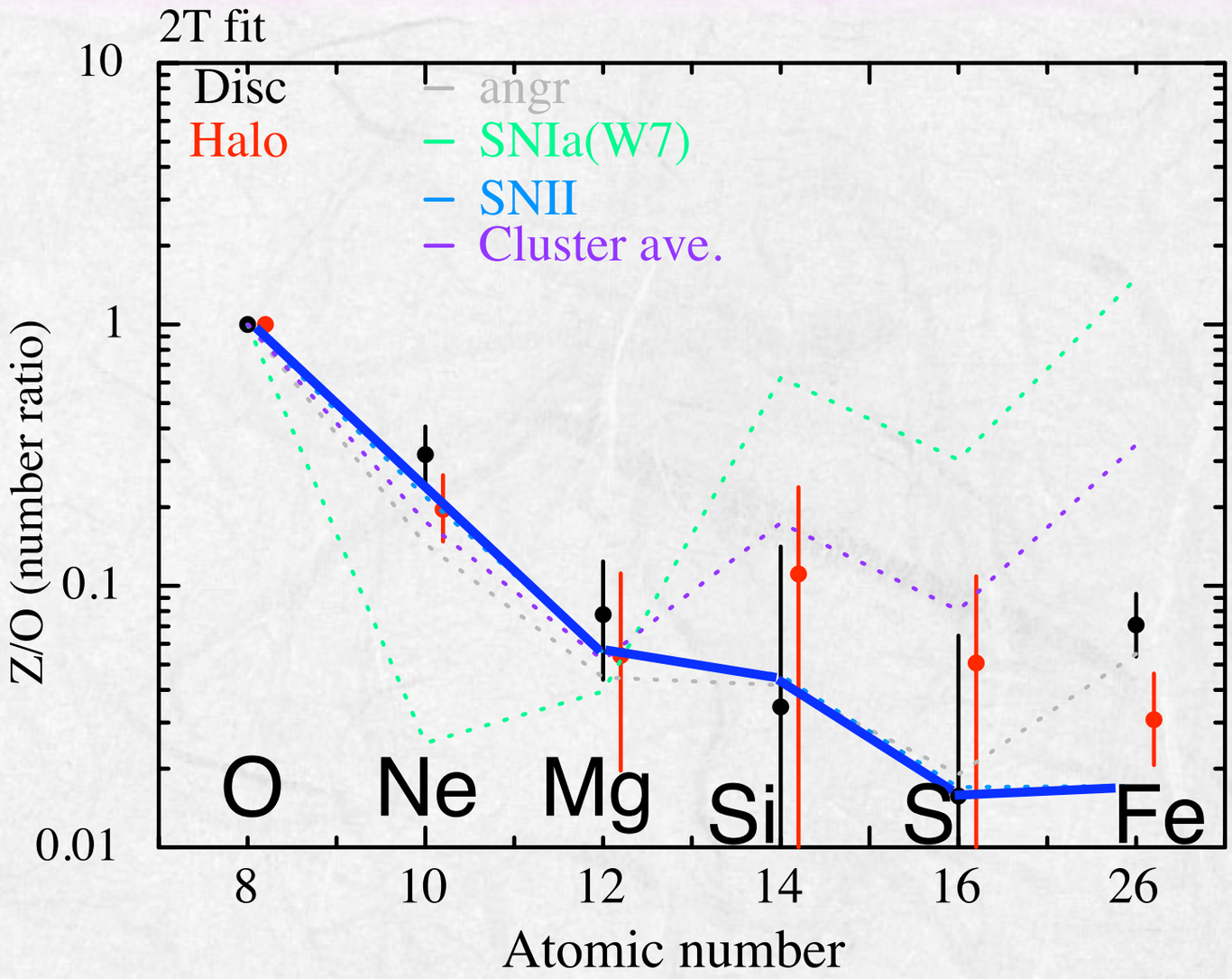
Spectra of Halo and Disk





	kT1 (keV)	kT2 (keV)	O	Ne	Mg,Al	Si,S, Ar,Ca	Fe,Ni	χ^2/dof
disk	0.21 +/-0.02	0.48 $^{+0.07}_{-0.1}$	0.73 $^{+0.69}_{-0.37}$	1.6 $^{+2.1}_{-0.7}$	1.26 $^{+0.7}_{-0.65}$	0.6 $^{+2.65}_{-0.6}$	0.93 $^{+0.64}_{-0.41}$	1172/1109
halo	0.1 $^{+0.07}_{-0.01}$	0.30 $^{+0.02}_{-0.03}$	0.81 $^{+0.55}_{-0.43}$	1.09 $^{+1.14}_{-0.55}$	0.98 $^{+1.14}_{-0.69}$	2.17 $^{+0.83}_{-2.17}$	0.46 $^{+0.31}_{-0.23}$	

Abundance pattern



Abundance of the halo is almost consistent with SNe II model averaged by IMF (Nomoto + 2006) .

⇒Halo gas is of SNe II products origin

Summary

- Suzaku can resolve OVII and OVII line clearly, and found that the Oxygen sky is variable and complex.
  - SWCX around the Earth (Comets, Mars etc.and in the heliosphere)
  - OVII from Local Bubble
  - Significant contribution from stars in the Galactic plane
  - Hot ISM in and aroud the Galaxy
- All can become “background” for all kind of observations.
  ⇒Many people has started to know the plentifulness of our neighborhood.
- Reproduction method of SWCX is underway.